and *Philhydrus* they are attached to plants and in *Helochares* are carried on the abdomen until hatched. The cocoons are formed by the secretions of two glands discovered by Stein.

Differences in color in *Helophorus* may be caused by the surroundings; darker specimens are found late in the fall by sifting and collecting in the woods, while lighter ones occur more in the open field. The species prefer sandy shores of slow running water, but are also found in stagnant water.

I was fortunate enough to capture one specimen of *Ochthebius foveicollis* Lec. for the first time in New Jersey by sweeping in clear stagnant water on *Myriophyllum*. Most of the species are Pacific and are said to prefer clear, running, shallow water, in which they may be found adhering to the underside of stones, preferably those partly out of water. Frequently they are found in small colonies.

The species of *Hydræna* are found here in stagnant water, but in California are said to occur in clear brook water, not under stones but in sand.

THE RELATION OF MOSQUITOES TO THEIR ENVIRONMENT.

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So far as known all mosquitoes are aquatic in their larval and pupal stages. Only a comparatively few, however, are able to exist for an indefinite period beneath the surface of the water, nearly all being forced to rise periodically to the top for a supply of oxygen. For this purpose a tube of varying length, according to the species, has been developed in the larva, and a pair of them, differently placed however, in the pupa. These tubes are in nearly all species thrust through the surface film and oxygen is obtained by direct contact with the outer air. In a few species, only one of which is found in the vicinity of New York, these tubes have become modified for a wholly underwater life. In these the tubes are so constructed that their tips may be inserted into the roots of plants and air obtained from or through the plants. In addition to the tube the larva is provided with four tracheal gills situated at the anal end of the body, and in a very

general way the larva is able to remain below the surface of the water for a greater or lesser period of time according as these organs are long or short. Thus, for example, the ordinary species of *Culex* (*sens. lat.*) have them of moderate length and remain beneath the water usually for about a minute; *Anopheles,* particularly *crucians,* and some of the less common species of *Culex* have them shorter and remain for a more brief period beneath the water; while *Culex dupreei* and *discolor* have them greatly developed and are in consequence capable of remaining under the water to all appearances indefinitely, though both are occasionally seen at the surface. In these latter cases the air-tube has become weak and is probable almost functionless. In *Wyeomyia smithii,* which remains under water during practically its whole larval life, two of the gills are greatly dilated while two are very much reduced in size.

There are probably no other insects which spend the whole of their early stages in water that pass through these stages so quickly as do the mosquitoes and in consequence these latter are able to utilize pools which would be quite too transient for other insects. A puddle in a wheel rut can and frequently does bring a brood of mosquitoes to maturity. But despite the fact that only a little water is required for their development, and that when experimentally removed from their place of birth the larvæ mature normally and in due season provided the water supplied them has a sufficient quantity of organic matter in it, the species under normal conditions are found in particular environments.

Our best known species, *Culex pipiens,* has very appropriately been called the domesticated mosquito by reason of its being invariably found around the habitations of man. Foul water seems to be its natural breeding place. Clear water however quiet and otherwise suitable is never selected. Sewage collected in a gutter, pails containing liquid manure, cesspools, rainbarrels, especially when but little water is at the bottom, are favorite breeding places. A small pond may be free from them except where refuse has been thrown in. And it is a noticeable fact that ordinary muddy water or such as becomes more or less polluted through natural agencies, as through dying vegetation, is not used as a breeding place. Pass beyond the limits of the village and city and *Culex pipiens* is no longer found, its place being taken by an allied species (*Culex restuans*) more

addicted to a clean water environment. *Restuans,* however, with one or two other species is not uncommonly found in the same situations as *pipiens.*

The salt marsh is an environment to which five species in this region confine themselves for breeding purposes. The mosquito fauna of the salt marsh is distinctive, none of the species living on it in the larval stage breeding anywhere else. *Culex sollicitans* is always the most abundant and is found in practically all the temporary pools uninhabited by fish. With it is found *Culex tæniorhynchus* and *Culex cantator.* The latter prefers those areas which merge into the fresh water marsh, such, for instance, as occur along rivers, rather than those which border the bays; but never is it found in strictly fresh water swamps. *Culex salinarius,* a not remote ally of the house mosquito, is the fourth species found on the salt marsh, and *Anopheles crucians* the fifth. The first three of these five species are migrants and are frequently found for many miles inland and away from the salt marsh, but never have the larvæ been found in fresh water pools. That the salt water is not a prerequisite for the development of the larvæ is evidenced by the fact that eggs of these species will hatch and the resulting larvæ mature in water that is absolutely fresh.

Another environment is the temporary pools of open fields, the more shallow open swamps which usually consist of a series of temporary pools more or less connected, and the shallow edges of ponds subject to the rise and fall of the water. These situations are all very similar when looked at from the mosquito-breeding standpoint, and contain practically the same species of mosquitoes. Thus *Culex sylvestris* is found in all of these places, though in smaller and more scattered numbers in the ponds, due probably to the greater struggle for existence. *Culex trivittatus, C. jamaicensis* and *C. discolor* are found in the same places, but to a less extent at the edge of the ponds. *Psorophora ciliata* occurs usually only in clear pools of the most transient character and two species of *Anopheles,* namely, *punctipennis* and *maculipennis* usually occur in such of these places as are to some extent overgrown with vegetation. The first of these two is occasionally found in pools with a clayey bottom and no vegetation, and in places inhabited by *Culex pipiens* but these are exceptions not often found. *Maculipennis* is more given to inhabiting pools and swampy regions at the edges of the woodland, or more rarely in the woodland itself.

In the colder and clearer parts of open swamps *Culex restuans,* occasionally found with *C. pipiens* as above mentioned, and *Uranotænia sapphirina* is often found; but *Uranotænia* together with *Culex perturbans* is more often found in permanent swamps. *Culex melanurus* occurs only in those places where the water is very cold and spring-like. Just why these species confine themselves to these environments is not known, but the fact that most of the species are able to maintain themselves well under other conditions would seem to indicate that the preferred environment is not important to the well-being of the species.

Passing from open fields and swamps to the woodland a totally different set of species are encountered. Most of these breed in the temporary pools formed by spring rains and melting snows, and frequently half a dozen or more species may be found in one pool. Approximately in the order of their abundance these species are: *Culex canadensis, C. abfitchii, C. subcantans, C. pretans, C. absserratus, C. musica, Ædes fuscus, C. sylvicola, C. dupreei, C. fitchii, C. pallidohirta, C. nivitarsis* and *C. inconspicuus.* Three others, *Culex aurifer* and *C. dyari,* so far found only in the woodland in the larger and more permanent bodies of water, and *C. saxatilis,* which has been found only once in a rock pool may be added. Three more are found normally in the woodland in very restricted situations. These are *Culex triseriatus, C. signifer* and *Anopheles barberi* which breed in the water contained in tree hollows. And another species which may be as much attributed to the woodland as to the more open swamps and which is even more closely associated with a particular environment is *Wyeomyia smithii,* the pitcher plant mosquito which has never been found breeding except in the leaves of the species of *Sarracenia* and of some orchidaceous plants.

The question that arises then is: What are the factors that more or less closely limit the distribution of these various species to their environment? We will briefly consider some of the conditions which influence mosquito habits.

It was at one time believed that all mosquitoes laid eggs in a similar manner—namely, in a boat-shaped mass which floated on the surface of the water. It is now known that eggs are laid in several different ways and that the conditions suitable for oviposition for one species is not suitable for another. Thus of the species around New

York *Culex pipiens, restuans, salinarius, melanurus, perturbans, territans,* probably *saxatilis,* and *Uranotænia sapphirina*—eight in all—deposit them in rafts. In order to insure safety to the larvæ two things must be observed by the parents: running water must be avoided, else the eggs will be washed away, and if in no other way destroyed by being carried to those ever ready for so dainty a morsel as an egg boat; and, the eggs must be deposited in a nook already comparatively free from enemies. Thus, these species are limited first to quiet water, and second to protected places in that quiet water. With regard to this latter nothing can be better than a pool so transient in character as to exclude the breeding of practically all other insects. When this can not be had the edges of shallow bodies are selected, particularly where protected by vegetation, rocks or debris. Such conditions are suited to most of the species in the egg-boat category, but other as yet unknown reasons induce some to select the fouler water (*pipiens*) and others (*restuans, territans,* etc.) the cleaner water. One species (*salinarius*) will select only salt water, and three others only permanent bodies of fresh water. The reason for the selection of permanent bodies in two instances (*perturbans* and *melanurus*) is known: the larvæ pass the winter in the larval stage and hence any water which would disappear during the fall or winter would cause the larvæ to perish. With *Uranotænia sapphirina,* the third species, the reason for the selection is not apparent.

The species which deposit their eggs singly may be placed in two distinct groups: those that deposit their eggs on the surface of the water and those that deposit them in the mud in depressions likely to be water filled. Only three species are positively known to have this last mentioned habit, all of them occurring on the salt marsh. It is well known that the salt marsh is subject to periodic inundation and desiccation. After such an area has been flooded all the pools are filled with larvæ, and a week or two later the adults emerge; but egg-laying does not begin until the meadow has become largely dry, when the mud is littered with eggs which remain unhatched for a month or a year, or several years if necessary, until covered by water, when the young larvæ emerge.

Many species are known to lay their eggs singly on the surface of the water but the group consisting of these species may again be divided into those of which the eggs hatch in a day or two as in the

species of *Anopheles,* and those of which the eggs sink and remain at the bottom unhatched for almost a year as in *Culex subcantans, pretans, absorratus,* etc. The former division, which continues to breed throughout the summer, usually selects the more permanent open swamps; the latter division selects woodland pools which last only during the spring months.

Vegetation in the water has much effect upon the mosquito life in it. Thus except in the most temporary rain pools mosquito larvæ and pupæ in water free from plants would be exposed to the attacks of many enemies and so be unable to maintain themselves. Vegetation serves as a protection to the eggs, the larvæ and the pupæ. On the other hand, if the vegetation is too dense it precludes the possibility of the larvæ gaining access to the surface (and most of them must do this, as had been said) and so literally drowns them; *Spirogyra,* the green scum found so commonly in stagnant water of a more permanent character, acts in much the same manner as the ordinary surface vegetation, but in addition to shutting off the air supply frequently entangles the larvæ and drowns them before they reach a point even near the surface. In the larger woodland pools where water beetles are abundant the larvæ naturally keep to the edges and cautiously move along the bottom under the protection of the sunken leaves.

Temperature likewise has considerable effect on the larvæ and pupæ, but scarcely as to influence choice of environment. In early spring these stages may together extend over a period of six weeks, while in midsummer the same species may pass from egg to adult in ten days. On the other hand a low temperature seems to have little effect on the hatching of the eggs. Some of the spring species may emerge from the egg in February, and an egg boat of *pipiens* will produce young as quickly when placed in spring water as when placed in rain water. Agitation seems to be of greater consequence than temperature in the hatching of the eggs. A rainstorm therefore will often hasten the eggs to hatch.

As to the distribution of mosquitoes all the species appear to be found wherever their respective environments occur. Thus while such species as *Culex abfitchii, canadensis, musica* and *pretans* are common in the wooded districts of the north of New Jersey they are also found in these same districts in the south of this state—in lesser

numbers only because wooded districts are there here in number and of less extent. *Culex atropalpus* which breeds in rock pools is found in Massachusetts and Connecticut and again along the Potomac River in Maryland. New Jersey is apparently passed by because she has no suitable rock pools to offer, her shores being made up of sands and marshes. *Wyeomyia smithii* is found in the leaves of the pitcher plant wherever this plant occurs, be it in the cedar swamps of southern New Jersey or the bogs of Warren Co. in the north of the state. *Culex triseriatus* and *signifer* likewise are found wherever tree cavities contain water for a considerable time. *Culex dyari,* it is true, while it may not be rare in the mountains in the northwest corner of the state will probably not be found in the lowlands in the south of the state; it seems to be a mountain species, and perhaps the exact conditions for it are not to be found except in the mountains. *Culex melanurus,* also, has so far been found only in the cold spring-fed bogs of South Jersey. *Culex perturbans,* on the other hand, is common in all portions of the state, low and high, where permanent swamps thickly overgrown with vegetation occur, and similarly *Culex aurifer* occurs in the more permanent woodland water areas along the cranberry bogs of the south and along the edge of Lake Hopatcong and other large ponds and lakes in the north. *Anopheles crucians* of the salt marsh is seemingly a more southern species, being always present in Cape May, less so in the vicinity of Barnegat Bay and positively rare around Perth Amboy and Elizabeth. *Culex tæniorhynchus* likewise has a tendency in this direction, being apparently a more southern species; yet occasionally it is met with in large swarms on the meadows of Long Island Sound.

Only two species known to me are given to breed in two distinct environments. These are *Culex sylvestris* and *Ædes fuscus.* The first of these is typically an open swamp species, but in the spring of the year is found in comparatively small numbers in typical woodland pools. The individuals from these woodland districts are smaller and darker than those produced later from the open swamps. The second is essentially a woodland species, but is occasionally found in numbers in open swamps, the converse of *sylvestris.* In this instance no differences are manifest between the adults produced in the different environments.